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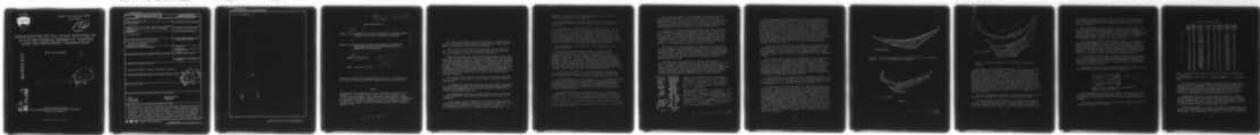
JUL 77 G M SHEYNFELDT

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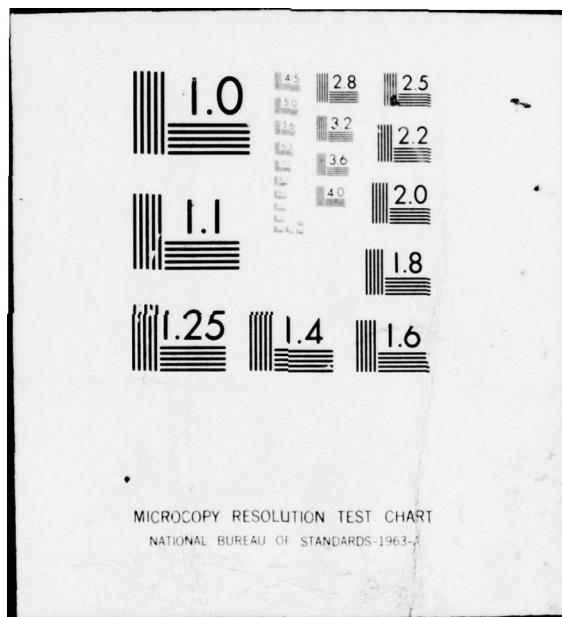
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ORGANIZATION OF FULL-SCALE ANALYSES OF FILTRATION-THERMAL REGIME OF TAILINGS DAMS ON PERMAFROST FOUNDATIONS

G.M. Sheynfeldt

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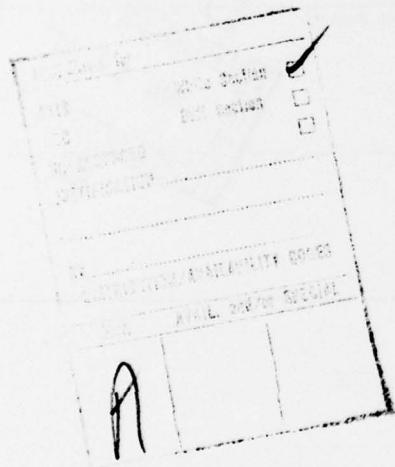
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→ and dam foundation.



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The intensive development of the mining industry of Yakutskaya ASSR involves the construction and operation of large tailings dumps under the specific conditions of severe climate and permafrost.

Today [several words illegible] tailings dumps with hydraulic fill dams 30-[illegible] m high, and in the near future tailings dumps with 50 m high hydraulic fill dams will be placed in operation.

Modern tailings dumps are a complex system that includes water transport, water [one word illegible] ([one word illegible] dikes and [one word illegible] tailings in [one word illegible] tailings dump), water drainage, water collecting and treatment facilities. For several reasons (inability to select the strength and water permeability characteristics of the fill material, [one word illegible] rate of buildup of the height and [two words illegible]), problems of the planning and operation of tailings dumps are more difficult than the planning and operation of water installations with local materials in the hydro-[one word illegible] and land reclamation [possibly complexes].

The difficulty also consists in the fact that the actual construction time of a hydraulic fill dam of a tailings dump is 10-20 years and sometimes longer.

The planning and operation of tailings dumps under arctic conditions have been carried out until the present time without standard documents or substantiated recommendations that consider the specific features of the climatic and permafrost conditions.

The strength and stability of tailings dump dams under arctic conditions are determined by the filtration and thermal mode of the dams and foundations.

At the present time the Krasnoyarsk Polytechnical Institute and the Yakutsk [two words illegible] Institute are conducting combined analyses of the geoengineering properties of tailings sediments, filtration and thermal mode of the soil of tailings dumps in Yakutskaya ASSR. The

purpose of the analyses is to evaluate and [one word illegible] the stability of hydraulic fill tailings dams.

The analyzed group of tailings dumps is located in a region with extremely severe climate, under the conditions of solid permafrost to a depth of 320 m.

The mean annual outside air temperature varies from minus 7.2°C to minus 13.4°C , and the absolute minima are, respectively, minus 63.0° and minus 64.5°C . The thickness of the permafrost layer varies from 1.0 to 2.0 m, depending on the exposure of the slope. The thickness of the snow cover in exposed sections is 35-[illegible] cm under natural relief conditions. The thickness of the snow cover on the slopes of the dikes and on the [possibly aquatorium] of the tailings dumps was not measured. The snow cover is established in early October and completely thaws in May.

The analyzed dams are characterized by the following [two words illegible] structure.

The strongly fractured permafrost bedrock, glacial in places, is made up of homogeneous or vertically and horizontally alternating strata of clay, marl and limestone (aleurolite and sandstone are sometimes encountered). On the valley and ravine walls the bedrock is covered by a layer of Quaternary sediments of insignificant thickness, gradually merging with the bedrock. The Quaternary sediments are made up basically of clay, loam, sandy loam and semi-[one or two words illegible] moraine -- marl and limestone with a varying concentration of gravel and clay particles, [possibly weathered] to the condition of loam. These rocks sometimes include thick (more than 1 m) strata and lenses of ice.

In the bed parts of ravines are deposited primarily strongly iced alluvial-slide rock sediments, consisting of sandy gravel, gravel-rubble and sand-rubble soils, covered in places with silt and silty loamy clay.

The thermal influence of a tailings dump leads to the thawing of foundation rocks, accompanied by constant filtration, which promotes further degradation of the permafrost. Substantial and irregular deformations of thawing foundations [one word illegible] the construction of strong and [two words illegible] sensitive foundations of such installations [eight words illegible] water, etc.

The granular composition of tailings sediments on which hydraulic fill tailings dams are built depends on the deposits processed by the plant -- placers or ores. For the former the mean weighted diameter of the initial tailings is $D_{av} = 0.59$ mm, and tailings with a diameter smaller than 200 [possibly micron] make up only 10% of the total, whereas for the latter $D_{av} = 0.06$ mm and the concentration of tailings with a diameter of 200 [possibly micron] ranges up to 85%.

The insufficient amount of large fractions in tailings sediments of placer plants necessitates the use of overburden rock for [one word illegible] dams. This rock usually consists of marl, which is sufficiently strong in its natural condition, but which is subjected to processes of metamorphization under the influence of a set of physical phenomena (fracturing, thawing, [one word illegible], atmospheric factors, etc.).

In June 1971, at one of the existing tailings dumps, were installed three experimental piezometers, designed to operate over a period of more than 2-5 years, and intended for determination of the characteristics of filtration flow in the most dangerous bed section of hydraulic fill dams. The design of the KPI piezometer differs from the standard in that it has independent filters at two levels and an internal annular settling bowl (Figure 1). The bottom filter is placed in the thawing part of the base of the dam, and the upper in the hydraulic fill part of the dam.

The design of the receiving part of the piezometer, designed by KPI, ensures its viability when its upper filter [possibly is] in contact with tailings sediments. The design of the piezometer takes into consideration the lack of local experience in the construction of a high-quality [possibly filtration] [one word illegible] and [one word illegible] winding of the filter in a deep drill hole with a [one word illegible] casing with an inside diameter of 118 mm.

The water level was measured in the standpipe of the piezometer, the diameter of which was equal to the outside diameter of the filter pipe. Therefore the inclusion in the piezometer design of an internal annular settling bowl and filters at two levels, guarantees the normal operation of the piezometer for a certain period of time, even with a poorly designed screen and external cushioning layer, on the condition that protection is provided against clogging and freezing from the surface.

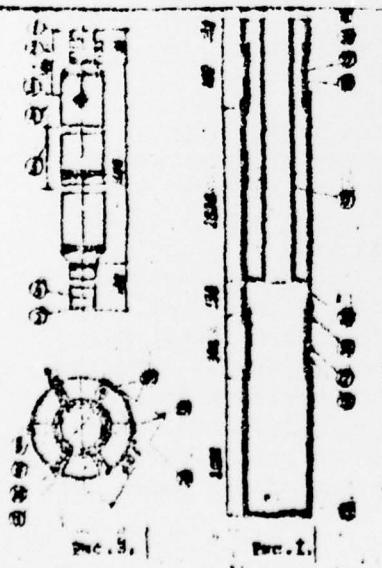


Figure 1. KPI piezometer with internal annular settling bowl: 15 -- [illegible]; 16 -- tube, $d = 100$ mm; 17 -- perforated [one word illegible]; 18 -- [possibly screens]; 19 -- inside [possibly tube]; 20 -- [two words illegible] of settling bowl; 21 -- [illegible].

Figure 3. VODGEO piezometer: 1 -- limiter; 2 -- [one word illegible] filter; 3 -- [illegible]; 4 -- [illegible]; 5 -- perforated [one word illegible] of [possibly upper] [one word illegible], length 1,500 mm; 6 -- tube 1.3 or 2.0; 7 -- thread for [one word illegible] coupling; 8 -- diameter 1.8-2.0; 10 -- settling bowl; 11 -- corrugated [one word illegible] screen; 12 -- [illegible]; 13 -- steel strip; 14 -- [illegible] (see Figure 4).

In consideration of the capabilities of local drilling technology the outside diameter of the piezometer tube was set equal to 100 mm, the dimensions of the water receiver part are 2×900 mm, the space between the perforations is 50 mm and hole diameter is 10 mm. The standard [one word illegible] winding, a layer of glass fiber fabric and corrugated screen [possibly corresponded] to a two-layer stainless steel screen with a [one word illegible] cell, drilling and casing conditions. The space between the casing and the [one word illegible] part was not filled with a coarse-grain cushioning layer. All of this maximally simplified the piezometer manufacture technology and resulted in more rigid requirements on the quality of the winding and [one word illegible] screen on the filter body, anti-corrosion coatings and on protection of the screen from damage during lowering into the drill hole.

A year and a half of experience in observations of the [possibly KPI] piezometers with a dual filter and internal annual settling bowl, without a [one word illegible] filter cushioning layer, makes it possible to judge their performance. These piezometers can be recommended for [two words illegible] piezometric drill holes with an operating life of up to [possibly 3 years].

At the present time, according to recommendations of the author and [possibly KPI] [one word illegible] of a tailings dam with a height of 30-50 m [two words illegible] with systems of piezometric and thermometric drill holes. At the time of completion of construction, the pioneering hydraulic fill tailings dams of the second unit of one of the plants was also equipped with thermometric drill holes. A detailed [one word illegible] of the equipping of tailings dams with a complex of [possibly calibrated] piezometric drill holes was completed with the participation of the author at the Institute [one word illegible].

Each tailings dump was equipped with three thermometric sections -- one in the bed part and two in the bank [one word illegible] of the dam, normal to its longitudinal axis. The bank sections were separated from the central by approximately 1/4 of the length of the dam (Figure 2a, b, c).

The thermometric drill hole sections were situated in the [one word illegible] at a distance of not more than 5-10 m from the piezometric drill hole section. During drilling of the thermo-piezometric drill hole samples were taken to determine the physico-[possibly chemical] properties of the tailings sediments in the [two words illegible]. A diagram of a typical thermo-piezometric section is presented in Figure 2. The given layout of the placement of the piezometers makes it possible to utilize the principle of separate determination of the parameters of two filtration flows, the upper, extending through the [possibly protected] part of the dam, and the lower, [possibly located] in the thawing, fissured rock horizons [one word illegible]. The [one word illegible] of these flows is attributed to the [one or two words illegible] effect of the layer of slide rock-alluvial loamy clay sediments, [possibly covering] a large portion of the basin area of all tailings dumps.

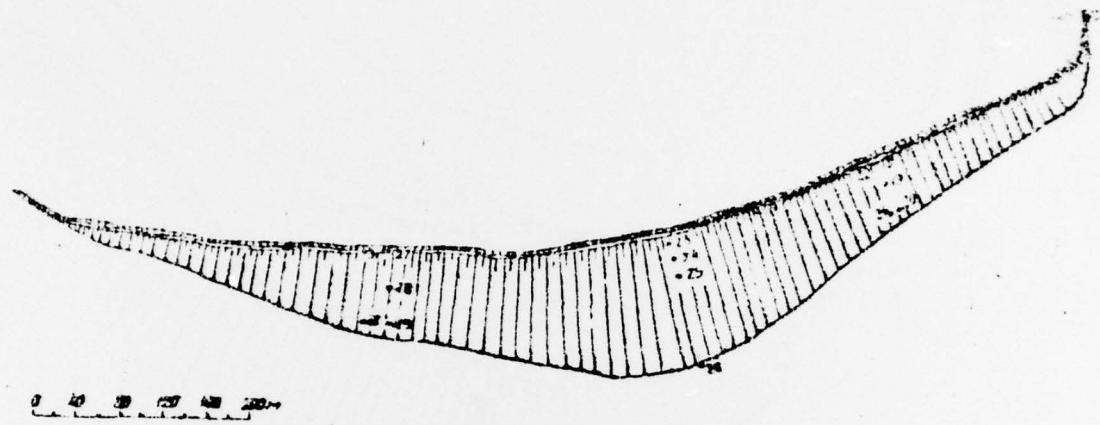


Figure 2a. Diagram of placement of KIA in tailings dump f.m.z. [Expansion unknown]. KIA -- control-measuring instruments.



Figure 2b.

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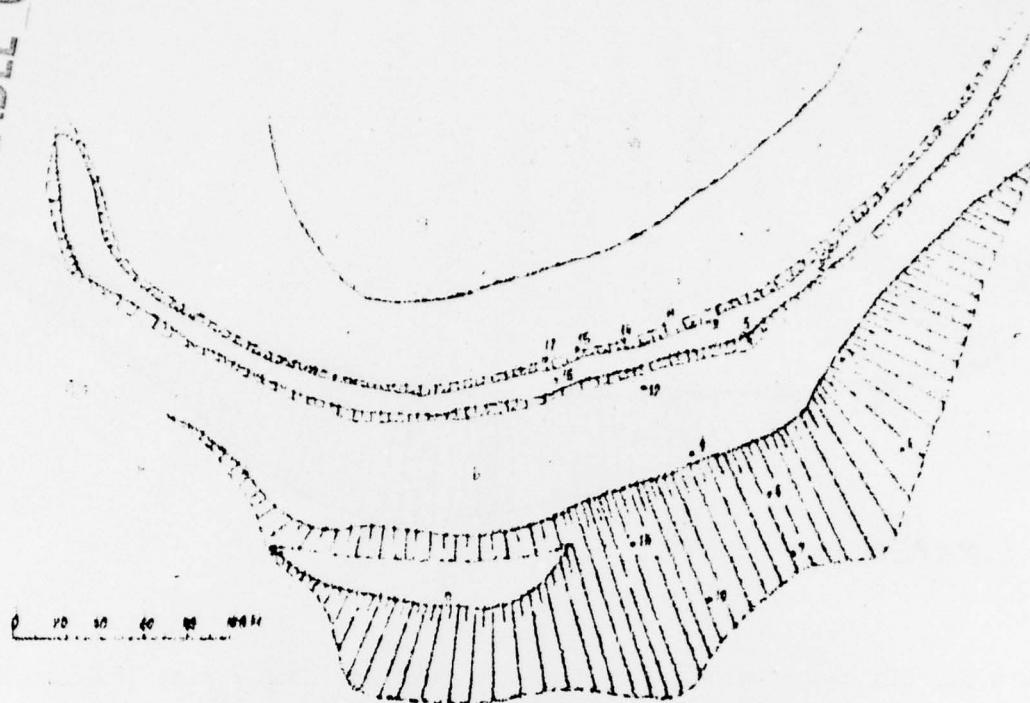


Figure 2c. Diagram of placement of KIA in tailings dump [possibly f.m.z.].

The diagram of a typical thermo-piezometric section provides for the placement of two kinds of piezometers -- PG [deep piezometer] and PO [lowered piezometer]. The lowered piezometer PO is designed for monitoring the filtration flow in the [possibly base] of a dam and for placement in drill holes, drilled in the intermediate [one word illegible], crest and [one word illegible] of the dam. The depth to which the piezometers were lowered was determined by data on the [one word illegible] structure and temperature state of the rocks, drilled through during prospecting boring, and also on the preliminary hydraulic fill dynamics of the temperature and filtration mode of the dam. In all cases the [one word illegible] distance from the [one word illegible] of the receiving filtering part of the piezometer and the [possibly exposed] surface of the dam was assumed equal to [one word illegible].

The deep piezometer PG was designed for monitoring [one word illegible] filtration in the [possibly thawed] layer from [one word illegible].

The receiving parts of these piezometers were installed at a depth of at least 5 [one word illegible] below the upper boundary of the fissured [one word illegible] rocks of the base. Within the upper impermeable layer of the base, which acts as a natural curtain, the space outside of the pipe

is maximally [one word illegible]. The deep piezometers installations that are being employed today are placed in position in consideration of data from prospecting drilling and temperature observation of the state of the bases of dams.

VODGEO [All-Union Scientific Research Institute of Water Supply, Sewer Systems, Hydraulic Engineering Structures and Engineering Hydrogeology] recommendations are used in consideration of their extended (at least 3 years) period of operation. The design of the receiving part of the piezometer is adaptable for placement in deep (up to 45 m) drill holes, in which the inside diameter of the removable casing pipe is 110 mm.

A distinguishing feature of this piezometer (Figure 3), in comparison with the typical Mekhanobr [All-Union Scientific Research and Planning Institute for the Mechanical Processing of Minerals] design, is the possibility of installing the receiving, filtering part of the piezometer in a drill hole without installing a drainage cushion after the placement of the piezometer. The filter is made entirely under [one word illegible] conditions and is connected to drill pipe sections by threaded couplers.

In consideration of the successful experience that has been accumulated in the use of stainless steel screen for making temporary piezometers, the vinyl screen and glass fiber fabric that are recommended in standard and permanent piezometers are replaced by a two-layer stainless steel [possibly screen] with a 0.5 mm mesh size.

The bodies of the filter part of the piezometers are filled with washed sand before being lowered into the drill holes (Figure 4).



Figure 4. Curve of granulometric composition of cushioning layer of filters.

The manufacture of the piezometers, assembly of the filter parts and connecting of the pipes with the threaded couplers were performed under the supervision of the author and did not involve any significant practical problems.

The mouth part of the piezometers was carefully warmed in a felt-filled wooden box immediately after assembly.

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Table of KIA Drill Holes

Номер	Номер	Способ	Глубина,	Номер	Номер	Способ	Глубина,
пункт	пункт	заряж.	м	пункт	пункт	заряж.	м
1	2	3	4	1	2	3	4
1	CT	210,67	29	14	PD	-	-
2	PD	214,70	20	15	PD	-	-
3	PD	213,57	10	16	DT	220,00	15
4	CT	193,42	20	17	PD	235,00	20
5	CT	215,75	10	18	PD	250,00	15
6	PD	208,22	10	19	DT	240,00	15
7	CT	184,88	20	20	CT	255,00	3
8	PD	214,10	20	21	CT	240,00	20
9	-	-	-	22	CT	205,00	40
10	CT	166,31	20	23	PD	195,00	4
11	CT	214,50	45	24	PD	205,00	30
12	CT	209,24	20	25	CT	190,00	10
13	PD	201,40	8	26	DT	190,00	22
14	CT	213,62	20	27	CT	205,00	50
15	CT	213,58	35	28	PD	205,00	12
16	PD	212,90	20	29	PD	195,00	3
17	CT	210,10	20	30	PD	185,00	15
18	PD	254,00	20	31	CT	185,00	20
19	PD	250,0*	15	32	CT	205,00	11
20	DT	240,00	15	33	PD	205,00	12
21	CT	240,0	20	34	PD	195,00	4
22	CT	254,00	40	35	DT	180,00	12
23	PD	-	-	36	CT	190,00	10

KEY: 1, Piezometric drill holes; 2, Kinds of drill hole*; 3, Top mark, m; 4, Depth, m.

*CT -- thermometric drill hole; PD -- lowered piezometer; DT -- deep piezometer.

The water level in the piezometers was measured every 10 days with an electrical contact level meter. The water level in the pond behind the tailings dump was recorded daily. During the measurements the location of discharge of tailings from the distribution [one word illegible] was recorded for the purpose of evaluating the effect of the pulp discharge point on the characteristics of the filtration flow within the dam.

Thermometric drill holes were bored into the bedrock at an average distance of 10-15 m apart; the depth to which these drill holes are bored into the permafrost rock zone is 6-10 m. This makes it possible to monitor the thawing of the base of the tailings dump over a long period of time and to take an arbitrary number of samples during drilling.

Ordinary thermometric drill holes, lined with 50 mm diameter pipe, the heads of which were covered with protective safes, were used for temperature observations. Rigid requirements were placed on the [one word illegible] of

the drill holes and [one word illegible] of their head zone to prevent the water filtering in from the beach from getting into the drill holes and space outside the pipe and to prevent distortions of the temperature field of the rocks, [possibly surrounding the drill hole].

The wells were equipped with [one word illegible] copper electrical resistance thermometers or thermistors. Periodic control measurements were taken with [one word illegible] mercury thermometers. The spacing between the transducers in the zone of seasonal temperature fluctuations and in the anticipated thaw zone of the base was [numbers illegible], and the average space between the transducers through the height of the well zone was 4.0 m. Measurements were taken every 10 days with an MO-62 electrical bridge.

Observations of the temperatures of the water in the pond and at the interface with the surface of the upper slope of the dam, in the same three cross sections, were conducted with thermistor transducers for the purpose of analyzing the thermal action of the tailings dump pond on the temperature mode of the hydraulic fill dam.

Data from the preliminary cycle of observations of one of the tailings dumps are presented in Figures 5 and 6. Analysis of these data shows that during 10 years of operation thawing of the permafrost rock occurred only in the foundations of the lower slope at a depth of up to 4-6 m. The thaw region does not extend beyond the [one word illegible] base of a pioneer hydraulic fill dam.

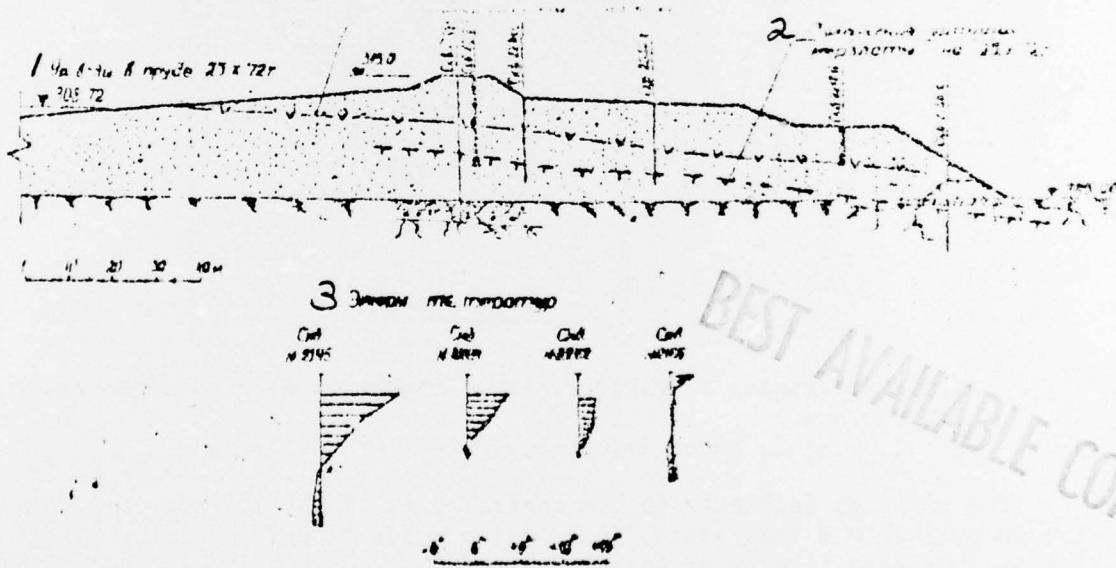


Figure 5. Results of first cycle of temperature and piezometric observations.

KEY: 1, Water level in pipe; 2, [Two words illegible] permafrost;
3, Temperature diagrams.

Data on the temperature mode of the rocks that make up the floor of a tailings dump within the zone of the pond have not yet been obtained.

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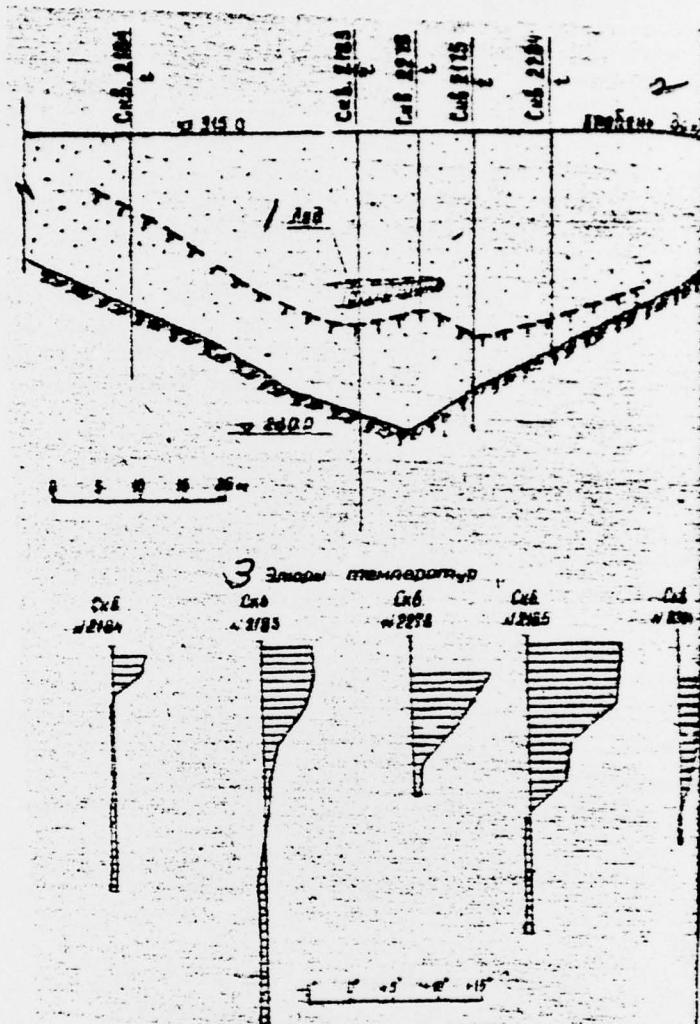


Figure 6. Results of first cycle of temperature and piezometric observations.

KEY: 1, Ice; 2, Water level; 3, Temperature diagrams

The tailings sediments in the central part of the profile of a dam are in primarily a thaw state, [one or two words illegible] lower stage, frozen [one word illegible] to a height of 10-12 m from the surface of the permafrost base. [One or two words illegible] thawed tailings sediments is a lens of subcrest ice, the temperature of which is near 0°C.

Comparison of the position and shape of the curve of [one word illegible] of the surface of the curtain, consisting of frozen tailings sediments leads to the preliminary conclusion that there is inside a hydraulic fill dam a filtering horizon, the thickness of which remains virtually constant through length. This conclusion, refined as a result of additional analyses of observations, substantially justifies calculation-theoretical forecasting of the formation of the temperature mode of the tailings sediments and dam foundation.